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4.1.3 Natural Ventilation

Natural ventilation is the use of wind and temperature differences to create airflows in and through buildings. These airflows may be used both for ventilation air and for passive cooling strategies. Natural ventilation is often strongly preferred by building occupants, especially if they have some control over it, as with operable windows. Studies have shown that most occupants will readily tolerate a wider range of ambient conditions if they have such control.

Before the advent of mechanical ventilation, all buildings were naturally ventilated. Since that time, climate-control expectations have risen significantly, and most building programs, codes, and regulations are based on the expectation of mechanical systems. Nevertheless, well-designed natural ventilation can often be used in conjunction with mechanical systems, creating a "mixed mode" building. Mixed-mode buildings may be designed around mechanical systems that are supplemented by natural ventilation or vice versa. The building may be designed to use both systems simultaneously or to switch from one to the other based on climate conditions or occupant demand. In a few situations, natural ventilation approaches can replace mechanical cooling and ventilation systems entirely.

Opportunities

Buildings constructed before about 1950 were almost always designed for natural ventilation, and it often makes sense to retain that function when renovating such buildings. Building types with less stringent climate-control requirements are the best candidates for natural ventilation, whether renovated or newly designed. Temperate climates with low relative humidity, such as in the northwestern United States, are best suited to natural ventilation.

Natural ventilation is most effective in increasing occupant satisfaction when it is combined with daylighting and when occupants are at least partially in control of the conditions. Unfortunately, giving control to occupants makes energy use by mechanical systems difficult to predict. Natural ventilation is most effective as an energy conservation strategy when combined with other passive cooling and cooling load reduction strategies, such as night flushing and effective shading.

Technical Information

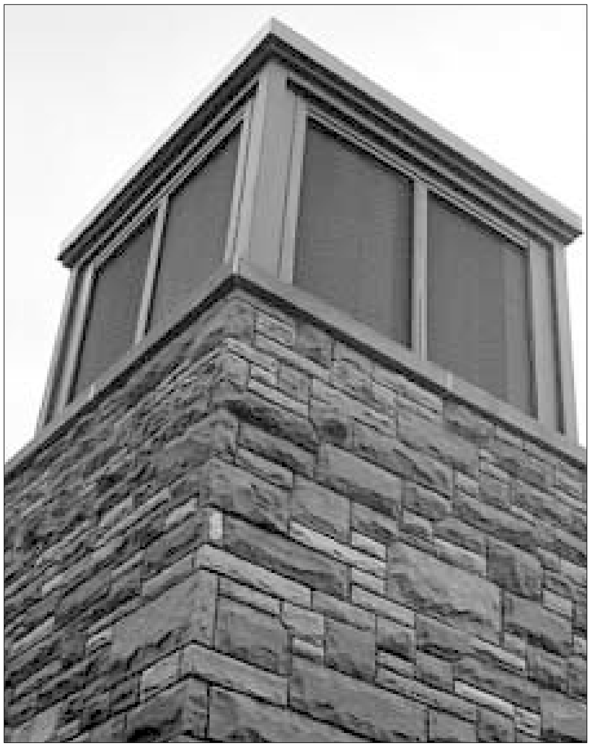
There are two basic types of natural ventilation effects: buoyancy and wind. Buoyancy ventilation is more commonly referred to as temperature-induced or stack ventilation. Wind ventilation supplies air from a positive pressure through apertures on the windward side of a building and exhausts air to a negative pressure on the leeward side. Shutters and louvres can also be positioned to maximize wind-induced airflow through the building. Airflow rate depends on the wind speed and direction as well as the size of apertures. Wind-driven turbine extractors are common in industrial buildings to provide natural ventilation.

In summer, the indoor-outdoor temperature difference is not high enough to drive buoyancy ventilation, and wind is used to supply as much fresh air as possible. In winter, however, the indoors is much warmer than outdoors, providing an opportunity for buoyancy ventilation. Also, ventilation is normally reduced to levels sufficient to remove excess moisture and pollutants in winter. For buoyancy ventilation, warm air in the roof rises and exhausts out of a high aperture, while cooler outdoor air comes in through an aperture at a lower elevation. Airflow rate depends on the size of these apertures, the height difference between them, and the indoor and outdoor temperatures. A "solar chimney" may be added to the exhaust to enhance the stack effect. An improvement sometimes used in arid climates is to add an evaporative cooler on top of a "cool tower"—this precools and pressurizes the inlet air and helps exhaust warm air high in the conditioned space or through the solar chimney.

Natural ventilation as a primary cooling and ventilation strategy is appropriate only under certain conditions. Temperate climates with low average humidity

OBSTACLES TO THE USE OF NATURAL VENTILATION

- Smoke control in case of fire is more difficult and may require special equipment and/or variances in codes.
- Outdoor noise is difficult to manage in a building that relies on operable windows or vents.
- Acoustic separation between spaces can be difficult to achieve.
- Low pressure differences often require large apertures for desired airflow rates.
- Outdoor air must be clean enough to introduce directly into occupied space. If filtration is required, mechanical ventilation is necessary.



Passive down-draft cool towers at the Visitor Center in Zion National Park (in Springdale, Utah) help bring temperatures down by cooling hot air with water at the top of the tower. This cooled air then falls into the building and onto the patio. Photo: Paul Torcellini

levels are the best candidates. In cold climates, mixed-mode buildings are viable, with natural ventilation as the primary source of outdoor air on a seasonal basis. Hot, humid climates tend to have the fewest days in which natural ventilation can be used without the risk of compromising comfort.

When natural ventilation is a priority for a new building or renovation, performance requirements should not include strict limits on acceptable indoor temperature and humidity conditions; this is because extreme weather conditions are difficult to predict. Instead, clear guidelines should be established for an allowable percentage of time to stray from certain conditions. The more broadly these conditions are defined, and the larger the acceptable amount of time out of compliance, the greater the possibilities for reducing mechanical system size and usage.

Naturally ventilated and mixed-mode buildings typically have floor plates less than 40 feet (12 m) wide—the floor plates of typical new large office buildings are too big for air to move reliably across them. Cooling-load reduction strategies—e.g., shading, heat-rejecting glazing, and the use of thermal mass to dampen temperature swings—are essential to maintaining comfortable conditions in buildings relying on natural ventilation.

Mixed-mode buildings may be designed to switch from mechanical to natural ventilation within the same space, or they may have both types of ventilation occurring simultaneously in separate spaces. Running both natural and mechanical ventilation simultaneously in the same space will usually lead to excessive energy use, especially if mechanical cooling or heating is active. In humid climates, switching back and forth between mechanical and natural ventilation may *increase* energy use, as the mechanical cooling system has to work harder to remove latent heat (moisture) that accumulates in the air and in materials in the building.

Design for passive airflow is complex, especially in large buildings. Specialized *computational fluid dynamics* (CFD) software is valuable in understanding airflow under different conditions, but such software is expensive and time-consuming to learn. Engineering firms with expertise in natural ventilation should have CFD software or access to it. The design of simple structures, such as livestock barns, often relies on simple but effective hand calculations to size the natural ventilation apertures.

For any building type, an understanding of local climate conditions is essential for good natural ventilation design. The free *Climate Consultant* software from the University of California at Los Angeles provides graphic displays of temperature and humidity conditions for most U.S. locations. It can be downloaded from www.aud.ucla.edu/energy-design-tools/.

$ Mixed-mode buildings tend to be more expensive than either mechanically ventilated or naturally ventilated buildings because of the duplication of air movement systems.

References

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